REMARKS

A Request for Continued Examination (RCE) and an Excess Claim Fee Letter for two (2) excess independent claims is submitted herewith.

Claims 1, 4, 5, 8, and 14-27 are all the claims presently pending in the application. Claims 1, 4, 5, 8, and 14-27 are amended to more particularly define the invention. No new matter has been entered.

It is noted that the claim amendments are made only for more particularly pointing out the invention, and not for distinguishing the invention over the prior art, narrowing the claims or for any statutory requirements of patentability. Further, Applicants specifically state that no amendment to any claim herein should be construed as a disclaimer of any interest in or right to an equivalent of any element or feature of the amended claim.

Claims 22-24 stand rejected under 35 U.S.C. § 102(b) as being allegedly anticipated by Harwig et al. ("Electrical Properties of β-Ga_2O_3 Single Crystals. II", Journal of Solid State Chemistry Vol. 23, pages 205-211, 15 January 1978).

Claims 16-18 stand rejected under 35 U.S.C. § 103(1) as being allegedly unpatentable over Harwig. Claims 1, 4, and 5 stand rejected under 35 U.S.C. § 103(a) as being allegedly unpatentable over Harwig in view of Ueda et al. ("Synthesis and Control of Conductivity of Ultraviolet Transmitting β-Ga_2O_3 Single Crystals", App. Phys. Lett. 70 (26), 30 June 1997). Claim 8 stands rejected under 35 U.S.C. § 103(a) as being unpatentable over Harwig in view of Ueda, and further in view of Ichinose et al. (U.S. Patent Publication No. 2004/0007708 A1). Claims 19-21 and 25-27 stand rejected under 35 U.S.C. § 103(a) as being allegedly unpatentable over Harwig.

The rejections mentioned above are respectfully traversed in the following discussion.

I. THE CLAIMED INVENTION

An exemplary aspect of the claimed invention (e.g. as recited in claim 1) is directed to A method of controlling a conductivity of a Ga_2O_3 system single crystal, including adding an n-type dopant to the Ga_2O_3 system single crystal to change a resistivity of the Ga_2O_3 system single crystal linearly with an added amount of the n-type dopant. The n-type dopant includes an n-type dopant for controlling the conductivity of the Ga_2O_3 system single crystal including one of Zr, Si, Hf, Ge, Sn, and Ti.

Another exemplary aspect of the claimed invention (e.g. as recited in claim 16) is directed to a method of controlling a conductivity of a Ga_2O_3 system single crystal, including contacting a Ga_2O_3 polycrystalline raw material including a predetermined dopant to a Ga_2O_3 seed crystal, and growing the Ga_2O_3 system single crystal on the Ga_2O_3 seed crystal such that the predetermined dopant is substituted for Ga in the Ga_2O_3 system single crystal to obtain a desired resistivity in the Ga_2O_3 system single crystal of 1×10^3 Ωcm or greater. The predetermined dopant includes a p-type dopant for controlling the conductivity of the Ga_2O_3 system single crystal, the p-type dopant including one of H, Li, Na, K, Rb, Cs, Fr, Be, Mg, Ca, Sr, Ba, Ra, Mn, Fe, Co, Ni, Pd, Cu, Ag, Au, Zn, Cd, Hg, Tl, and Pb

Conventional methods of controlling the conductivity of a Ga_2O_3 system single crystal have been used to control resistivity of the Ga_2O_3 system single crystal when a conductive property is required. Conventional methods, however, possess several different drawbacks. It is difficult using conventional methods to widely control the resisitivity because a substrate or thin film made of the Ga_2O_3 system single crystal naturally tends to have an n-type conductive property. It is also difficult using conventional methods to make a substrate or thin film of the Ga_2O_3 system single crystal having a high insulating property despite the necessity of such a Ga_2O_3 system single crystal (Application at page 3, lines 8-21).

On the other hand, an exemplary aspect of the claimed invention includes a method of controlling a conductivity of a Ga_2O_3 system single crystal, including adding an n-type dopant to the Ga_2O_3 system single crystal to change a resistivity of the Ga_2O_3 system single crystal linearly with an added amount of the n-type dopant (Application at Figure 2). Further, another exemplary aspect of the claimed invention includes a method of controlling a conductivity of a Ga_2O_3 system single crystal, including growing the Ga_2O_3 system single crystal on the Ga_2O_3 seed crystal such that the predetermined dopant is substituted for Ga in the Ga_2O_3 system single crystal to obtain a desired resistivity in the Ga_2O_3 system single crystal of 1×10^3 Ωcm or greater (Application at page 20, line 16 to page 21, line 15).

Since the claimed invention provides that the resistivity of the Ga_2O_3 system single crystal is linearly changed in correspondence to a dopant concentration of the n-type dopant added, for example, the resistivity and the carrier concentration of the Ga_2O_3 system single crystal can be linearly changed and controlled by adding a certain amount of n-type dopant with a predetermined concentration to the Ga_2O_3 system single crystal as shown in Figure 2 of the Application. Thus, it is possible to fabricate a Ga_2O_3 system single crystal of which resistivity is changed linearly.

II. THE PRIOR ART REJECTIONS

A. The Harwig and Ueda References and Alleged Combination

Harwig discloses the doping of β-Ga_2O_3 single crystals to influence electrical conductivity of the single crystals (Harwig at page 205). Ueda discloses the doping of a β-Ga_2O_3 single crystal with Sn (Ueda at Abstract). The Examiner alleges that Harwig anticipates the claimed invention and the combination of Harwig and Ueda makes the claimed invention obvious. Applicants respectfully disagree.

Even assuming (arguendo) that one of ordinary skill in the art would combine Harwig and Ueda, the resultant combination fails to teach or suggest all features of the claimed invention. Specifically, both Harwig and Ueda, either alone or assuming (arguendo) combination, clearly fail to teach or suggest a method of controlling a conductivity of a Ga_2O_3 system single crystal a method of controlling a conductivity of a Ga_2O_3 system single crystal, "*comprising . . . adding an n-type dopant to the Ga_2O_3 system single crystal to change a resistivity of said Ga_2O_3 system single crystal linearly with an added amount of the n-type dopant*", as recited, for example, in claim 1 (Application at Figure 2), or "*comprising . . . growing the Ga_2O_3 system single crystal on the Ga_2O_3 seed crystal such that said predetermined dopant is substituted for Ga in the Ga_2O_3 system single crystal to obtain a desired resistivity in the Ga_2O_3 system single crystal of 1 X 10^3 Ωcm or greater*", as recited, for example, in claim 16 (Application at page 20, line 16 to page 21, line 15).

1. THE INVENTION OF CLAIM 1

With respect to the exemplary feature of the invention of claim 1, none of the cited prior art references provide that the resistivity of the Ga_2O_3 system single crystal is linearly changed in correspondence to a dopant concentration of the n-type dopant added. In addition, the motivation to combine the cited prior art references to accompish this exemplary feature of the claimed invention is not described in any of the cited prior art references.

Harwig describes a temperature dependence of the resistivity in cases where Zr or Mg are doped by mixing Ga_2O_3 having a purity of 4N (the contained impurities are as follows: 100-200 ppm of Si, 20-50 ppm of Ca, 20-50 ppm of Mg, and 50-100 ppm of Al) with ZrO_2 or MgO (Harwig at Figure 1).

However, Harwig neither teaches nor suggests that the conductivity that is being controlled by changing the doping concentration is linearly controlled. Meanwhile, Harwig teaches that only a small amount of Zr or Mg can be added to β-Ga_2O_3.

Namely, for example, referring to Harwig, page 206, lines 4-12 of the left column, Harwig teaches that a dopant in the concentration of only about several hundred ppm can be doped, even though a dopant is being intentionally added to β-Ga_2O_3, and that the impurity concentration in the undoped crystal is, for example, 100-200 ppm in Si. In more detail, Harwig teaches that the conductivity of $10^{-5} - 10^{-3}$ Ωcm^{-1} was obtained when the Zr concentration was 1000 ppm (300-500 K) and the conductivity of $10^{-6} - 10^{-4}$ Ωcm^{-1} was obtained when the Zr concentration was 100 ppm (450-700 K). Applicants note that none of the conductivities taught by Harwig were evaluated at room temperature.

In other words, Harwig teaches that, when a dopant is doped into β-Ga_2O_3, only the dopant lower than the impurity concentration level (190-400 ppm) can be doped. This doping capability indicates that, in fact, it is nor possible to measure whether the dopant is doped into β-Ga_2O_3, and that the conductivity cannot be controlled by the dopant concentration.

On the other hand, in the claimed invention, when the dopant is doped into β-Ga_2O_3 having high purity (e.g., 6N), the Si dopant concentration is changed to 1 X 10^{-5}- 1 mol% (0.064-6400 ppm) by changing the doping concentration, for example to a room temperature, thereby enabling to linearly change the conductivity to 1.25 X 10^{-3}-500 $\Omega^{-1}cm^{-1}$.

Thus, the teaching of Harwig is different from the claimed invention. Harwig does not teach or suggest that the resistivity is linearly changed in correspondence to the dopant concentration.

To make up for the deficiencies of Harwig with respect to the invention of claim 1, the Examiner applies Ueda. In Ueda, the conductivity is controlled by changing oxygen partial pressure during a bulk growth of β-Ga_2O_3 using a Ga_2O_3 material having a purity of 4N to which an impurity is not added (Ueda at page 3561, right column, 1-2 lines from the bottom, page 3562, left column, 1-12 lines from the top, and Figure 1).

However, Ueda, in which the conductivity is controlled by changing the oxygen partial pressure, fails to teach or suggest that the conductivity is controlled by changing the doping concentration of the dopant, like that of the claimed invention. This is obvous from Figure 1 of Ueda. Applicants note that, in Figure 1 of Ueda, the conductivity is changed to 0.63-0.9 $\Omega^{-1}cm^{-1}$ by changing an oxygen flow rate to 0.05-0.5 m^3h^{-1}.

In addition, referring to Figure 1 of Ueda, a measurement result is taught in which the conductivity becomes 0.96 $\Omega^{-1}cm^{-1}$ when doping 0.05 mol% of Sn with Ga_2O_3 having a purity of 4N. However, from the teachings of Ueda, it is clearly not obvious how the conductivity changes with respect to the doping level from only one measurement result, even for one having ordinary skill in the art.

Applicants note that, referring to the left column in page 3562 of Ueda, it is taught that the conductivity of the β-Ga_2O_3 single crystal becomes 38 $\Omega^{-1}cm^{-1}$ when the N_2/O_2 partial pressure is 0.4/0.6. In addition, Figure 2 of Ueda teaches a temperature dependence of the conductivity of the β-Ga_2O_3 single crystal when the N_2/O_2 partial pressure is 0.4/0.6. As taught in Figure 2, it is understood that the conductivity falls within a range of 30-40 $\Omega^{-1}cm^{-1}$. Thus, referring to Figure 1, when the N_2/O_2 partial pressure is 0.4/0.6, and, namely, when the O_2 flow rate is 0.12 m^3h^{-1}, the plot does not become 38 $\Omega^{-1}cm^{-1}$. As mentioned above, since a portion which lacks consistency exists in the teachings of Ueda, it does not appear that Ueda is appropriate as a cited prior art reference against the claimed invention.

Thus, neither Harwig nor the alleged Harwig and Ueda combination teach or suggest the invention of claim 1.

2. THE INVENTION OF CLAIM 16

With respect to the exemplary feature of the invention of claim 16, Applicants respectfully submit that Harwig and Ueda clearly fail to teach or suggest a method of controlling a conductivity of

a Ga_2O_3 system single crystal to obtain a carrier concentration in the Ga_2O_3 system single crystal within a range of 5.5×10^{15} to $2.0 \times 10^{19}/cm^3$ or to obtain a desired resistivity in the Ga_2O_3 system single crystal of 1×10^3 Ωcm or greater. Indeed, Harwig certainly fails to teach or suggest the carrier concentration and the desired resistivity of the claimed invention.

On page 8, second paragraph of the Office Action, the Examiner admits that the exemplary features highlighted above are neither taught nor suggested by Harwig or Ueda, either alone or assuming (arguendo) combination. To make up for these deficiencies, the Examiner alleges that "the combined teaching [of Harwig and Ueda] teaches an identical process, such as doping a predetermined dopant to the Ga_2O_3 single system crystal, and an identical material, such as n-type dopant."

However, the Examiner contradicts himself. On page 7, final paragraph of the Office Action, the Examiner admits that the purity of Harwig is not the same as is included in the claimed invention. Thus, there is no rational way the combination of Harwig and Ueda can teach or suggest the desired resistivity and carrier concentration of the claimed invention as the Examiner alleges. Further, since the exemplary features are clearly not taught or suggested by Harwig or Ueda, there is no rational way the Examiner can allege that the admitted difference is obvious to one of ordinary skill in the art.

Further, Applicants respectfully submit that claims 25-27 are not taught or suggested by any of the cited prior art references. Specifically, none of the prior art references teach or suggest Si, Hf, or Sn as n-type dopants added to a Ga_2O_2 system single crystal.

Therefore, Applicants respectfully request the Examiner to reconsider and withdraw the rejection.

B. The Ichinose Reference

To make up for the deficiencies of the alleged Harwig and Ueda combination, the Examiner applies Ichinose. Ichinose discloses a light emitting element (Ichinose at Abstract). The Examiner alleges that the combination of Harwig, Ueda, and Ichinose makes the claimed invention obvious.

However, even assuming (arguendo) that one of ordinary skill in the art would combine Harwig, Ueda, and Ichinose, the resultant combination fails to teach or suggest all features of the claimed invention. Specifically, Ichinose, like Harwig and Ueda, clearly fails to teach or suggest suggest a method of controlling a conductivity of a Ga_2O_3 system single crystal a method of controlling a conductivity of a Ga_2O_3 system single crystal, "*comprising . . . adding an n-type dopant to the Ga_2O_3 system single crystal to change a resistivity of said Ga_2O_3 system single crystal linearly with an added amount of the n-type dopant*", as recited, for example, in claim 1 (Application at Figure 2), or "*comprising . . . growing the Ga_2O_3 system single crystal on the Ga_2O_3 seed crystal such that said predetermined dopant is substituted for Ga in the Ga_2O_3 system single crystal to obtain a desired resistivity in the Ga_2O_3 system single crystal of $1 X 10^3$ Ωcm or greater*", as recited, for example, in claim 16 (Application at page 20, line 16 to page 21, line 15).

Ichinose teaches that Ga_2O_3 single crystal is obtained by a FZ method using a Ga_2O_3 polycrystalline, and that Mg is added (e.g., Ichinose at paragraph [0096]). However, Ichinose clearly fails to make up for the deficiencies of the alleged Harwig and Ueda combination with respect to the above-referenced exemplary features of the claimed invention.

Therefore, Applicants respectfully request the Examiner to reconsider and withdraw this rejection.

III. FORMAL MATTERS AND CONCLUSION

Further, Applicants respectfully submit that claims 25-27 are not taught or suggested by any of the cited prior art references. Specifically, none of the prior art references teach or suggest Si, Hf, or Sn as n-type dopants added to a Ga_2O_2 system single crystal.

In view of the foregoing, Applicants submit that claims 1, 4, 5, 8, and 14-27, all the claims presently pending in the application, are patentably distinct over the prior art of record and are in condition for allowance. The Examiner is respectfully requested to pass the above application to issue at the earliest possible time.

Should the Examiner find the application to be other than in condition for allowance, the Examiner is requested to contact the undersigned at the local telephone number listed below to discuss any other changes deemed necessary in a telephonic or personal interview.

The Commissioner is hereby authorized to charge any deficiency in fees or to credit any overpayment in fees to Attorney's Deposit Account No. 50-0481.

Respectfully Submitted,

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